Reducing the Cost
(and Increasing the Availability) of Low-Expansion, Fused Glass Mirror Blanks

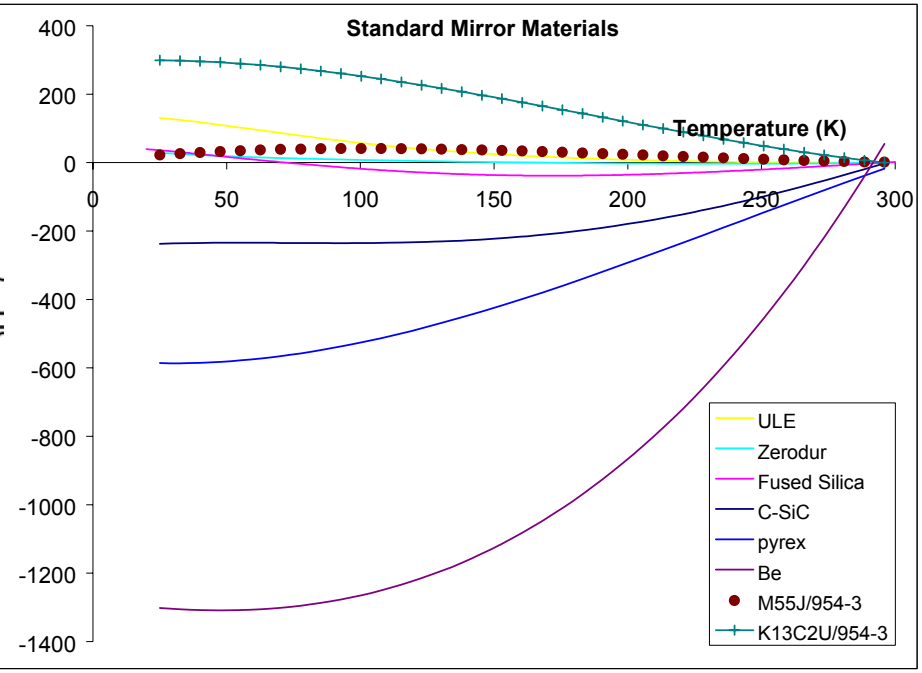
Dr. Steven Connell
ATK-Composite Optics, Inc.

Outline

- Historical Background of ULE™ Mirror Blanks
- JWST Mirror Cost Target and Other NASA Mission Budgets
- Technologies for Mirror Blank Cost Reduction
  - "Recycling" of ULE™ Residuals from Previous Blanks
  - Glass Fusion Qualification at ATK-COI
  - Tooling Cost
  - Standardized Design Library
- Examples of COI Produced Blanks
- Conclusions

ULE™ Mirror Background

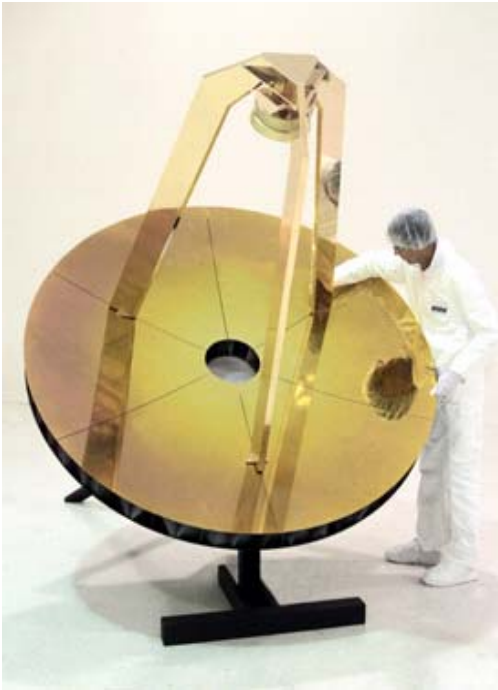
- **Description**
  - » **Low Expansion - Stable - Athermal with Graphite Composites.**
- **History**
  - » **Premiere Missions**

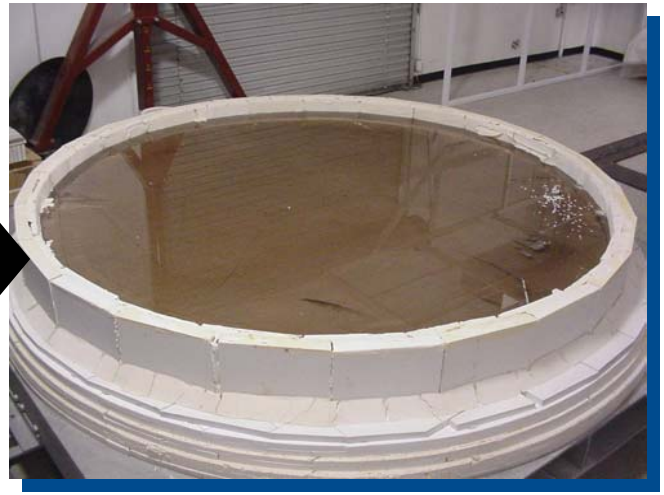


COI Involvement with ULE™ Processing

ULE™ Reclamation

- **FIRST (Herschel) Composite Mirror Development**
  - » **Needed Large, Low-Expansion, but Low-Cost Glass Tool**
  - » **Developed Process to Re-flow ULE™ Remnants**
  - » **100” x 5” Glass Blank Successfully Created**
  - » **Key Furnace/Facility Acquisitions**





How Can We Benefit Our Customers with Furnace Capability?

COI Involvement with ULE™ Processing
AMSD Mirror Fusion and Slumping

- **KODAK – COI Partnership to Accomplish AMSD**
  - **Kodak**
    - **Technology Heritage**
    - **Produce All Parts and Ship to COI**
    - **Key Personnel and Equipment**
  - **COI**
    - **Provide Furnace and Cleanroom Facilities**
    - **Support Personnel**
    - **Assist in Troubleshooting**
  - **“Natural” Technology Transition**

How Can We Benefit Our Customers with Furnace and/or Blank Capability?

JWST
Cutting Edge of Mirror Technology

- **Mirror Blank Cost Target**
  - 2X – 3X Cost Reduction vs. Historical
  - ~ $0.5M / m^2
- **Kodak-Corning Partnership for "Blank Factory"**
  - "Mass Produce" Identical Segments to Create Large Aperture (e.g., Economies of Scale benefits)
  - Efficient Cost Structure When 'Hopper Is Filled'
  - Heritage and Risk Reduction Critical Factors

How Can We Benefit Our Customers with Furnace and/or Blank Capability?

Other Opportunities
NASA Mission Budgets

- Missions of Opportunity (Science Support of Non-NASA Missions)
  - ~$30M
- Explorer (Orbital Astronomy and Space Physics)
  - SMEX - $75M
  - MidEX - $150M
- ESSP (Earth Science)
  - $175M
- Discovery (Planetary Science)
  - $300M
- Mars
  - Scout - $325M
- New Frontiers (Solar System Exploration)
  - $650M

- Common Characteristics
  - Ambitious Performance Goals
  - Large Composites Content
  - Cost Constrained (Cost Effective Mirror Solution is Enabling)
  - Single Unit, Custom Design

Technologies to Improve Cost (and Increase Availability) of Fused ULE™ Mirror Blanks

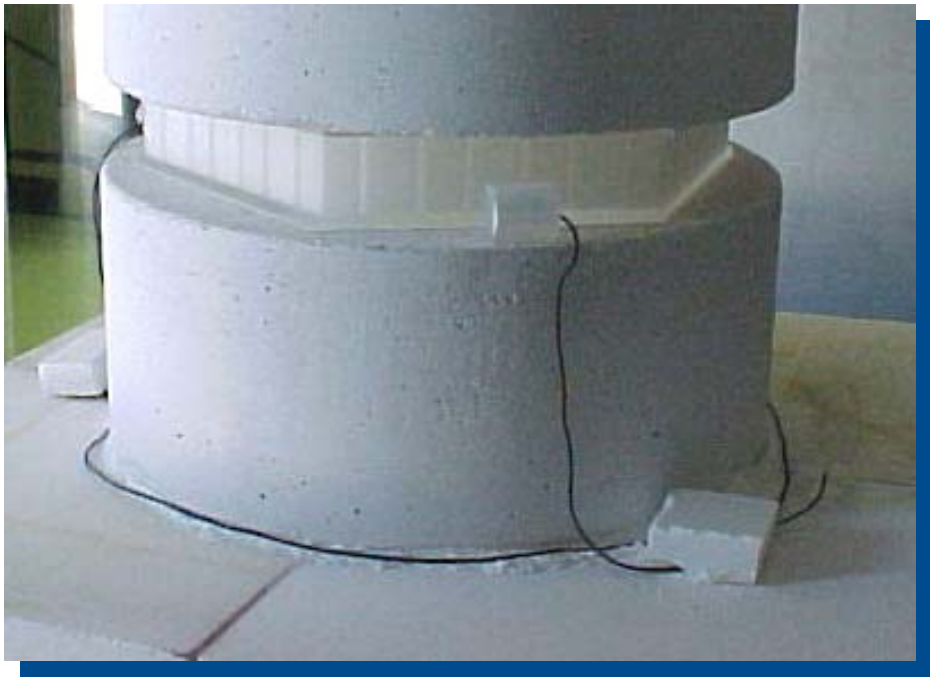
- **Non-Recurring**
  - Low Cost Tooling
- **Recurring**
  - Fusion Process Qualification at ATK-COI
  - “Recycled” ULE™ for Prototyping / Development

Low Cost Tooling

- **Tooling Requirements**
  - Creep Resistant
  - Chemical Compatibility with ULE™
  - Size Capability Consistent with Mirror Dimensions
- **Candidates**
  - Fused Silica
    - \+ Successful Heritage
    - \- Expensive
  - NZP Ceramic
    - \+ Extremely Stable - No Interaction with ULE™
    - \- Maximum Size = ~24”
  - Alumina or Other Common Refractory Ceramics
    - \+ Large, Low Cost, High Availability
    - \- Incompatible with ULE™

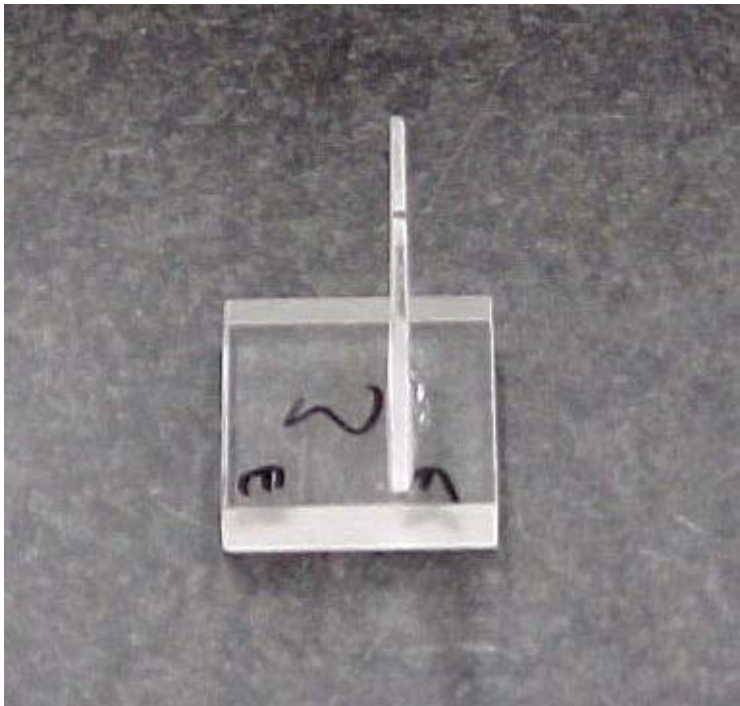
Low Cost Tooling (cont.)

- **ALTERNATE: COI Fused Silica - Ceramic**
  - **Superior Stability at Fusion and Slump Temperatures**
  - **Castable in Sizes Up to 2+ Meters**
  - **Compatible with ULE™ (Low Alumina Content)**
  - **Density Similar to Fused Silica**
  - **LOW COST**
    - **~$5 / Pound vs. ~$100+ / Pound for Fused Silica**



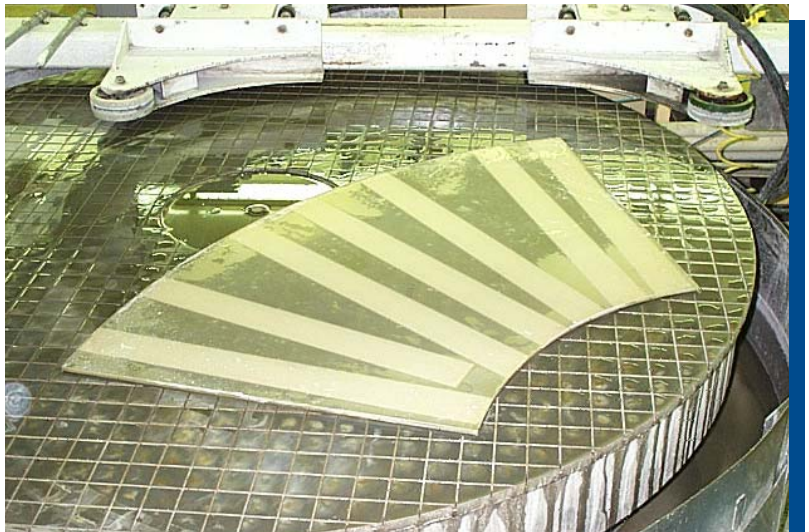
Fusion Process Qualification

- Qualify Aggregate and/or Individual Process Step Variations by Fusion and Destructive Test of “T-Samples”
- 100+ Coupons Fused and Destructively Tested
- Fusion Quality Typically >95% (Bond Area Successfully Fused)
- Average Bond Strength = 3080 +/- 400 psi

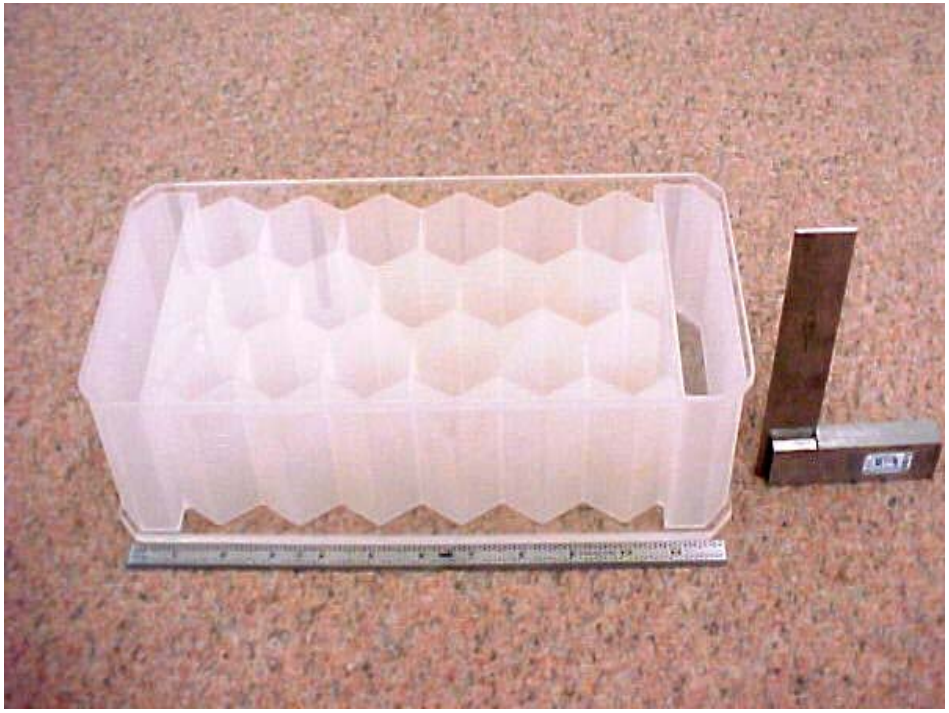


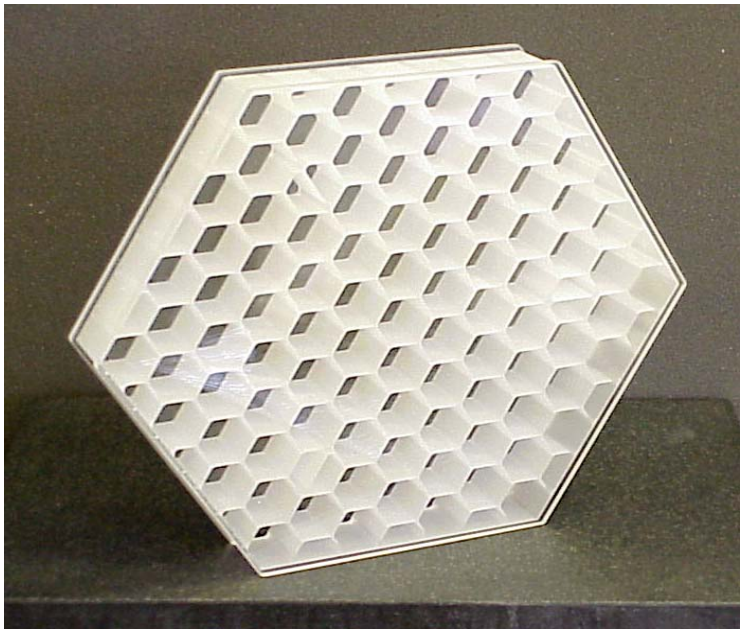
ULE™ Reclamation

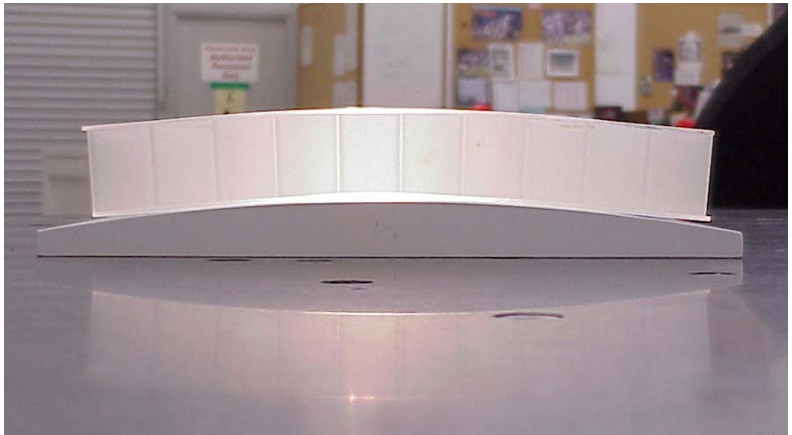
- **"Mature" Process**
  - **4 Years of Development. ~100 Plates Fabricated, from 6" to 100".**
  - **Tailorable to Any Size of Available Residual "Scraps" (min. ~4")**
  - **Tailorable to Any Size/Shape of Finished Plate**
- **Retention / Improvement of CTE Properties / Distribution**
- **All COI Fusion Qualification and Mirror Fabrication Done to Date Using Reclaimed Plates**



COI Produced Mirror Blanks







Future Work

- 2003 IRAD Objectives
  - Qualify All Processes for Fusion at ATK-COI to Typ. Flight Loads
  - Improve Understanding of Slumping
- 2003 CRAD Objectives
  - Fabrication and Mech. Test of ~1m Class Demo
  - 2 Proposals Pending
  - Other Opportunities?
- TRL Level 5 / 6 in 2004

Conclusions

- ULE™ Mirror + Composite Structure = High Performance Telescope
- COI Has Developed Technology, Facilities, and Personnel to Produce Fused ULE™ Mirror Blanks
- Technology Development Has Also Focused on Ways to Reduce Historical Cost
  - Low Cost Tooling
  - Fusion Qualification at COI
  - ULE™ Reclamation
- Capability Ideally Suited for Unique Missions (and/or Demos) with High Composites Content and Aggressive Budgetary Constraints